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Test Report MM-II-TR-020

MINUTEMAN III STAGE III S-901 FIBERGLASS STORAGE LIFE ASSESSMENT

February 1987

Aerojet Strategic Propulsion Company

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I. SUMMARY

The first year of an aging study on S-901 fiberglass used in the Minuteman III Stage III Remanufacture Program has been completed.

Owens-Corning Fiberglas Corporation (OCF), the sole source supplier of the S-901 fiberglass used in both the Polaris A3R and Minuteman III Stage III Remanufacture Program, is planning to stop production of the S-901 fiberglass in 1988. This is six to eight years before the end of the Minuteman III Stage III Production contract. As a result, S-901 fiberglass will be stored at 0°F for six to eight years, prior to resin impregnation and chamber fabrication. This study was conducted to determine if the S-901 fiberglass rovings will meet all specifications after this length of storage. Keywords: fiberglass, Guided

The study was completed using two lots of S-901 fiberglass residual to a Polaris aging study, 5 and 6.5 years old at the time of the dry fiberglass testing, and newly manufactured fiberglass from the Minuteman III Stage III remanufacture program. The S-901 fiberglass used in the Polaris program is the same as used in the Minuteman program, so the testing of this material gave 6.5 years real-time aging data for the Minuteman remanufacture program. Results show the S-901 dry fiberglass and resin impregnated fiberglass (with EF-2 resin) meet all specifications after storage up to 6.5 years with no aging trends.

A second year of S-901 fiberglass testing has been proposed with an option for a third year of testing if second year test results indicate the S-901 fiberglass meets all specifications. These tests will verify the predicted fiberglass aging trends, and verify the the S-901 fiberglass can still be used in chamber fabrication after about nine years storage.

II. BACKGROUND/INTRODUCTION

Owens-Corning Fiberglas Corporation (OCF) is the sole source supplier of the S-901 fiberglass roving used in the Polaris A3R and the Minuteman III Stage III Remanufacture Program.

The S-901 fiberglass roving, referred to as "dry fiberglass," is packaged and stored at a temperature of 0°F and subsequently resin impregnated by Ferro Corporation prior to chamber fabrication.

OCF is planning to stop production of S-901 fiberglass in 1988 which is six to eight years before the end of the Minuteman III Stage III Production Contract.

The dry fiberglass roving has reactive sizing designed to cure with the impregnated resin matrix. Changes in the degree of fiberglass sizing polymerization is of primary concern when the dry fiberglass is required to be stored for several years.

The Polaris Program had a similar concern when in 1981 OCF announced that it planned to cease production of WS 1126 S-901 fiberglass in 1983, approximately three years before the last need date for Polaris A3R production. As a result the Polaris A3 Program developed a program to verify the required three year storage life of S-901 fiberglass. The program was successfully completed in September, 1983 with fiberglass tested ranging up to 57 months in age. No adverse aging trends were noted from this study. Twenty-one balls of S-901 fiberglass rovings were residual from this study and fiberglass from two lots were selected for use in the Minuteman study. Test results from the Polaris aging study are directly comparable to the Minuteman study, though the resin system used at Ferro and OCF for the S-901 fiberglass tensile tests has been changed because of a shortage of the WS 1126 required vinyl resin. The resin system presently used by Ferro Corporation and OCF is EF-2. The Polaris study was conducted using a vinyl resin with Exon 461 as an ingredient. Manufacture of Exon 461 ceased a few years ago; however, Aerojet had a sufficient quantity of Exon 461 to conduct tensile tests for comparison with the Polaris test data. Testing to verify the storage life of S-901 fiberglass rovings was conducted using both the vinyl resin and the EF-2 resin. The use of the two resins allowed a continuation of the Polaris data base as well as providing tensile data to compare results of WS 1126/ASPC 34421 and ASTM-D2343 procedures.

III. TEST APPROACH

Two lots of S-901 fiberglass, residual to the A3R Program, 5 and 6.5 years old at the time of the dry fiberglass tests, and newly manufactured S-901 glass from the Minuteman III Stage III Remanufacture Program were tested. The fiberglass lots tested were as follows:

		Dry Fiberglass		Impregnated Fiberglass	
Lot	Manufacture Date	Test Date	Age (Months)	Test Date	Age (Months)
2988	9-18-79	3-86	78	8-86	83
3143	2-02-81	3-86	61	8-86	66
3512	11-19-85	3-86	4	8-86	8

The S-901 fiberglass was tested according to the test methods and specifications shown in Tables I and II. Tests were also conducted according to ASTM Procedures in order to develop data correlations with the WS 1126 and WS 1028 test methods. Dry fiberglass tensile tests were conducted using both the EF-2 resin system presently used by Ferro Corporation and vinyl resin for comparison to the Polaris Test Program.

Table I. Dry Fiberglass Test Matrix[1]

	Test	Test Method	No. of Specimens per Ball	Total No. of Tests per Year
1.	Ignition Loss, Wt. %	WS 1126/ASPC 34421	3	15
2.	Weight per linear yd, gms/yd	WS 1126/ASPC 34421	3	15
3.	Tensile Strength, psi	WS 1126/ASPC 34421[2]	3	15
4.	Tensile Strength, psi	ASTM D2343 Procedure A[2]	5	25
5.	Tensile Strength, psi	ASTM D2343 Procedure B[2]	5	25
6.	Horizontal Shear Strength, psi a. @ 250°F b. After 2-hour water boil	WS 1126/ASPC 34421	5	25
7.	Horizontal Shear Strength, psi a. @ 250°F b. After 2-hour water boil	ASTM D2344	 5 5	 25 25
8.	Acetone Extraction, Extractables, Wt. % and Insolubles for S Glass and Roving	AR-I-8A[3]	3	15
9.	Extraction/GPC Analysis	AGC Analytical Methods	3	15
		TOTAL	40	200

(1) These tests will be conducted using 2 S-901 balls each from aged Lots 2988, 3143, from the Polaris study, and 1 ball from Lot 3512 from the Minuteman III Stage III Remanufacture Program.
(2) Tensile Strength Tests using Vinyl and EF-2 Resin.
(3) Owens-Corning Fiberglas Corporation Test Method (Soxhlet Apparatus)

Table II. Impregnated Fiberglass Test Matrix(1)

	Test	Test Method	No. of Specimens per Ball	Total No. of Tests per Year
1.	Volatiles, Wt. %	WS 1028/ASPC 34422	3	15
2.	Ignition Loss, Wt. %	WS 1028/ASPC 34422	3	15
3.	Weight/Linear Yd, gm/yd.	WS 1028/ASPC 34422	3	15
4.	Resin Flow, Wt. %	WS 1028/ASPC 34422	3	15
5.	Gel Time, Minutes	WS 1028/ASPC 34422	3	15
6.	Horizontal Shear Strength, psi	WS 1028/ASPC 34422		
	a. @ 250°F		5	25
	b. After 2-hour water boil		5	25
7.	Horizontal Shear Strength, psi	ASTM D2344		
	a. @ 250°F		5	25
	b. After 2-hour water boil		5	25
8.	Tensile Strength, psi	WS 1028/ASPC 34422	3	15
9.	Tensile Strength, psi	ASTM D2343 Procedure A	5	25
10.	Tensile Strength, psi	ASTM D2343 Procedure B	5	25
		TOTAL	48	240

(1) These tests are conducted after Dry Glass Tests are completed. After Dry Glass Tests, the remaining material from the same balls is resin impregnated and returned to ASPC for these tests. Shipments are packaged in an insulated container packed with dry ice.

IV. TEST PROGRAM

A. DRY FIBERGLASS TESTS

Dry fiberglass tests were conducted in accordance with the test matrix shown in Table I, to determine if the aged S-901 roving is within the following ASPC 34421/WS 1126 acceptance limits:

Test	Acceptance Limits
Ignition loss, Wt %	1.00-2.25
Tensile Strength	400,000 psi Minimum (Polaris, WS 1126)
	440,000 psi Minimum (Minuteman, ASPC 34421)
Horizontal Shear	
(1) At 250°F	1,000 psi Minimum
(2) After 2 Hr Water Boil	6,000 psi Minimum
Acetone Extraction	70% Minimum

Testing was also conducted to make a comparison of the ASPC 34421/WS 1126 test methods with the ASTM test methods. Dry fiberglass test results are listed in Table III and in the following sections.

1. Ignition Loss and Roving Weight Loss Per Linear Yd

This test determines the amount of organic material that is removed from the roving after it has been exposed to 1500°F for a minimum of 15 minutes. Ignition loss is determined for the dry fiberglass roving and the impregnated fiberglass roving. For the dry fiberglass roving, the material burned off is the sizing. For the impregnated fiberglass roving the material burned off is both the resin and sizing. After testing for ignition loss, the roving's weight per linear yard can be determined. This value is used in the tensile strength calculations for the dry fiberglass roving and impregnated fiberglass roving.

The ignition weight loss versus age for up to 6.5 years age is shown in Figure 1. Test data from the Polaris study are shown for comparison. All fiberglass tested was within the specifications requirements and no aging trends are indicated.

2. Tensile Strength

"Dry fiberglass" tensile strength tests are conducted on fiberglass rovings impregnated with a polymeric binder material (vinyl or EF-2) at Aerojet. Impregnated tensile tests are conducted on fiberglass roving impregnated at Ferro Corporation.

Tests were conducted using both the Vinyl resin for comparison to the Polaris Test Program and the EF-2 resin system presently used by Ferro Corporation. Tests were conducted according to the Minuteman/Polaris Specifications ASPC 34421/WS 1126 and to ASTM D2343 Procedures A and B in order to establish a correlation between the three test methods. The basic difference between the ASPC 34421/WS 1126 and ASTM tests is the loading rate. The ASPC 34421/WS 1126 specifies a loading rate of 0.10 inches per minute, and the ASTM method specifies a loading rate of 0.50 inches/minute. The resulting increase in the straining rate usually results in a corresponding increase in tensile strength. The differences between the ASTM Procedures A and B are the grips used. Procedure A calls for cardboard tabs used with serrated jaws, while Procedure B tests are conducted without tabs, using rubber face grips. ASPC 34421/WS 1126 tests are conducted without tabs, using rubber face grips.

Test results are shown in Figures 2 through 6. WS 1126 tests conducted using the vinyl resin were compared to the Polaris Test Program in Figure 2. No aging trends are indicated, and the test data is above the Polaris minimum acceptance limit of 400,000 psi. Figure 3 compares the tensile strength versus aging time of S-901 fiberglass impregnated with vinyl resin versus EF-2 resin, and tested according to the ASPC 34421/WS 1126 test method. Figures 4 and 5 show the tensile strength versus aging time of fiberglass tested according to ASTM D2343 Procedure A and ASTM D2343 Procedure B, respectively. A comparison of fiberglass impregnated with vinyl resin versus EF-2 resin is made. Comparison of the EF-2 and vinyl resins, in Figures 3 through 5, shows the fiberglass impregnated with the EF-2 resin has 10 to 30% higher tensile strength than glass impregnated with the vinyl resin, and it meets the Minuteman ASPC 34421 minimum acceptance requirement of 440,000 psi for all three test methods. Although a few of the individual samples tested, which were impregnated with EF-2 resin, did not meet the minimum Minuteman requirement of 440,000 psi; acceptance is based on an average of three or more samples, and the average value for all lots tested met the requirement.

A comparison of the three test methods used ASPC 34421/ WS 1126, ASTM Procedure A and ASTM Procedure B, is shown in Figure 6. No clear difference in the results obtained by the three test methods and no aging trends are indicated. The S-901 fiberglass meets the Minuteman ASPC 34421 tensile strength requirements after storage up to 6.5 years.

3. Horizontal Shear Strength

The Horizontal Shear Strength of unidirectional fiber reinforced composite (the strength of the composites under shear stress acting parallel to the fiber) is measured by the short beam shear test. In this test the specimen consisting of a short beam in the form of a segment cut from a N.O.L. ring specimen is subjected to symmetric three-point bending. The beam is loaded until fracture occurs, and the fracture load is interpreted as measure of the shear strength of the material.

Two test methods were used to evaluate the shear strength. They were the Polaris/Minuteman WS 1126/ASPC 34421 test method and the ASTM D2344 test method. Both test methods were used to establish baseline data for future specification changes. The difference between the two methods are as follows:

(a) The loading nose required in ASPC 34421/WS 1126 is a flat face 0.25 in. x 0.25 in. inpressor. Where as, the loading nose required in ASTM D2344 is a 0.250 inch diameter dowel pin with a hardness of 60 to 62 HRC and has a finely ground surface free of indentation and burrs with all sharp edges relieved.

(b) The ASPC 34421/WS 1126 specifies a specimen length of 0.920 inch (length-to-depth ratio of 3.68), while the ASTM D2344 specifies a length-to-depth ratio of 7.

The short beam shear tests were conducted on fiberglass at 250°F and on fiberglass boiled in distilled water for 2.0 hours and then tested at 80°F.

Results of the 250°F shear test, shown in Figure 7, are well above the ASPC 34421/WS 1126, 1,000 psi minimum acceptance limit for both the ASPC 34421/WS 1126 and ASTM D2344 test methods. No aging trends are apparent. Results for the ASTM D2344 test method were slightly lower than obtained for the ASPC 34421/WS 1126 test method.

Results of the shear tests on specimens tested at 80°F after a two hour water boil are shown in Figure 8. Specimens tested by both the ASTM and ASPC 34421/WS 1126 test methods meet the specifications. Results for the ASTM test method were equivalent to results obtained for the ASPC 34421/WS 1126 test method. No aging trends are apparent. These test data will be used as a data base for determining acceptance limits for the ASTM test method, if this method is used in the future.

4. Acetone Extractables

The primary degradation of the S-901 dry fiberglass is the polymerization of the reactive sizing over time. The degree of polymerization is determined by the acetone extraction tests. New fiberglass has extractables in the 95% range. It has been determined that when the extractables reach 70%, the processability and physical properties of the impregnated S-901 roving is unsatisfactory.

This test is conducted by exposing a specified weight of dry fiberglass roving to acetone in a soxhlet extraction apparatus for a specified length of time and then determining the percent extractables. The same specimen is then ignited and the weight percent extraction loss and weight percent insolubles are calculated.

Figure 9 shows the results for the acetone extractables for Polaris study test results. The Polaris test results showed fiberglass from two lots tested, lots 2907 and 2908, had much lower extractables then the other lots tested. With the exception of these two lots the Polaris study showed no significant aging trends. Lots 2988 and 3143 tested in this study, residual to the Polaris study, are shown in Figure 10 with a comparison made to earlier test results for these lots from the Polaris study and newly manufactured glass, lot 3512. The S-901 fiberglass tested do not show any statistically significant loss of extractables due to aging after up to 6.5 years storage.

5. Gel Permeation Chromatography

Preliminary Gel Permeation Chromatography (GPC) tests were conducted with inconclusive results.

The GPC tests are to be used for comparison purposes to establish a correlation between Gel Permeation Chromatography and acetone extractables. These tests are not part of the specifications requirements. Further GPC testing is planned during the Follow-On Test program.

B. IMPREGNATED FIBERGLASS TESTS

Upon completion of the dry fiberglass test, the same fiberglass balls were packaged in an insulated container with dry ice and shipped to Ferro Corporation for EF-2 resin impregnation. Testing was conducted in accordance with the test matrix shown in Table II. The tests will determine if the S-901 roving will be within the following ASPC 34422/WS 1028 acceptance limits:

Test	Acceptance Limits
Volatiles Wt %	3.0 Maximum
Ignition Loss Wt %	17.0 - 23.0
Resin Flow Wt %	5.0 - 12.0
Gel Time Minutes	1.0 - 3.5
Horizontal Shear	
(1) At 250°F	1,000 psi Minimum
(2) After 2 Hr. Water Boil	6,000 psi Minimum
Tensile Strength	380,000 psi Minimum (Polaris, WS 1028)
	440,000 psi Minimum (Minuteman, ASPC 34422)

Impregnated fiberglass test results are listed in Table IV. The results of each test is described in the following sections.

1. Volatiles

This test is conducted by subjecting a specified length of preweighed impregnated roving to a temperature of 275°F for 15 minutes in a vented oven, allowing to cool, and reweighing. The resulting weight loss is calculated as the volatile content. This loss of volatiles is the amount of residual solvents remaining in the resin system after impregnation.

Figure 11 shows the range of test data obtained for the three lots tested in this study. As seen from the figure, the volatile content is well below the 3.0 % maximum acceptance limit for up to seven years storage. No aging trends are apparent.

2. Ignition Loss and Roving Weight Loss Per Linear Yard

This test, described in Section IV.A.1, determines the amount of organic material removed from the roving after exposure to 1500°F for 15 minutes. As shown in Figure 12, the ignition weight loss is within the specifications acceptance limits for the lots tested, which ranged up to seven years in age.

The roving weight loss per linear yard is determined after the ignition loss test and is used in the tensile strength calculations.

3. Resin Flow

Resin Flow tests are conducted by sandwiching three-inch lengths of impregnated fiberglass roving between four layers (two on each side of the specimen) of fiberglass cloth. The sandwiched material is then pressed on a flat plate maintained at 300°F by a 1500 gram metal weight (preheated and maintained at 300°F). The glass cloth containing excess resin is removed, and the preweighted samples are reweighed. The resulting weight loss is calculated as resin flow.

The resin flow weight loss versus age is shown in Figure 13 for the fiberglass tested. The average resin flow calculated the three lots tested, ranging up to seven years in age, were within the specifications acceptance limits and no aging trend was indicated.

4. Gel Time

A small section of impregnated fiberglass roving is placed under controlled heating conditions, and a liquid drop of resin is squeezed out. The time it takes for the small drop of resin to change from a liquid phase to a solid phase is the gel time. The gel time versus age is shown in Figure 14. The gel time is within the specifications acceptance limits for storage up to seven years. No aging trends were indicated.

5. Horizontal Shear

The Horizontal Shear tests are described in Paragraph IV.A.3. Figures 15 and 16 show the horizontal shear of the impregnated fiberglass at 250°F and after a two-hour water boil. As seen from the figures, the horizontal shear strength is well above the specifications minimum acceptance limits, for samples tested, using both the ASPC 34422/WS 1028 and ASTM D2344 test methods, after storage for up to seven years. The short beam shear of samples, subject to a 2 hour water boil, which were tested according to the ASPC 34422/WS 1028 test method were about 20% higher than samples tested according to the ASTM D2344 test method. There was no difference in the results obtained, for the two test methods, for fiberglass short beam shear at 250°F. No aging trends were indicated.

6. Tensile Strength

The tensile strength test methods are the same as those in Section IV.A.2, except the impregnated roving test specimens are prepared without the resin coating required for the dry fiberglass tests.

The tensile strength of the impregnated fiberglass rovings versus age is shown in Figure 17. The average tensile strength value was above the 440,000 psi minimum for three test methods used. There are no differences between the values obtained for the three test methods. No aging trends were indicated.

V. CONCLUSIONS

The ASPC 34421/WS 1126 specification tests were conducted on three lots of dry S-901 fiberglass ranging in age from 4 to 78 months at the time of testing. All dry fiberglass tested are within the specifications acceptance limits. No aging trends are indicated for any of the parameters tested.

The ASPC 34422/WS 1028 specification tests were conducted on three lots of S-901 fiberglass impregnated with EF-2 resin ranging in age from 8 to 83 months at the time of testing. All tested S-901 fiberglass, impregnated with EF-2 resin, are within the specifications acceptance limits. No aging trends are indicated for any of the parameters tested.

Based on these real-time aging study test results, the dry and impregnated S-901 fiberglass meets all Minuteman specifications after 6.5 years storage. Based on the calculated zero aging trends, the S-901 fiberglass is also predicted to be within the ASPC 34421 and ASPC 34422 acceptance limits after a minimum of eight years storage. A storage life limit for the S-901 may be predicted with additional testing.

VI. REFERENCES

1. Test Plan MM-II-TP-020, Minuteman III Stage III S-901 Fiberglass Aging Program, October 1985

2. Polaris Weapons Specifications - WS 1126, WS 1028 and Minuteman Specifications ASPC 34421, ASPC 34422

3. American Standard Test Methods - ASTM D2343, Procedures A and B, ASTM D2344

Table III. Dry Fiberglass Test Results, Sheet 1 of 7

Items 1 and 2. Ignition Loss and Weight Per Linear Yard

Lot No.	Ball No.	Ignition Loss, Weight %		Weight Per Linear yard, gms/yd	
2988	12	2.10	$\bar{x}$ 3	0.602	$\bar{x}$ 3
		1.79	2.01%	0.597	0.598
		2.14		0.596	
2988	14	2.19	$\bar{x}$ 3	0.600	$\bar{x}$ 3
		1.69	1.99%	0.600	0.600
		2.08		0.599	
3143	23	1.70	$\bar{x}$ 3	0.580	$\bar{x}$ 3
		1.62	1.67%	0.602	0.588
		1.70		0.583	
3143	29	1.61	$\bar{x}$ 3	0.608	$\bar{x}$ 3
		1.64	1.61%	0.601	0.603
		1.59		0.600	
3512	44291	1.66	$\bar{x}$ 3	0.605	$\bar{x}$ 3
		1.68	1.62%	0.607	0.606
		1.52		0.607	

Table III. Dry Fiberglass Test Results, Sheet 2 of 7

Item 3. Tensile Strength Per WS 1126/ASPC 34421

Lot No.	Ball No.	Tensile Strength, psi Vinyl Resin		Tensile Strength, psi EF-2 Resin	
2988	12	470401	$\bar{x}$ 3	523746	$\bar{x}$ 3
		518896	473634 psi	509773	515047 psi
		431605		511622	
2988	14	418083	$\bar{x}$ 3	500250	$\bar{x}$ 3
		480917	437417 psi	468833	505889 psi
		413250		548583	
3143	23	478401	$\bar{x}$ 3	458673	$\bar{x}$ 3
		443878	461139 psi	510459	500595 psi
		461139		532653	
3143	29	444859	$\bar{x}$ 3	461692	$\bar{x}$ 3
		452073	449668 psi	514594	500166 psi
		452073		524212	
3512	44291	442657	$\bar{x}$ 3	567079	$\bar{x}$ 3
		416337	442657 psi	507261	543152 psi
		468977		555116	

Table III. Dry Fiberglass Test Results, Sheet 3 of 7

Item 4. Tensile Strength Per ASTM D2343 Procedure A

		Tensile Strength, psi			
Lot No.	Ball No.	Vinyl Resin		EF-2 Resin	
2988	12	363712		547993	
		387960	$\bar{x}$ 5	533445	$\bar{x}$ 5
		451003	404933 psi	526171	528595 psi
		404933		528595	
		417057		506773	
2988	14	483333		519583	
		471250	$\bar{x}$ 5	517167	$\bar{x}$ 4
		459167	461583 psi	541333	526229 psi
		449500		526833	
		444667		444667*	
3143	23	404422		493197	
		424150	$\bar{x}$ 5	527721	$\bar{x}$ 5
		456207	412313 psi	500595	506020 psi
		401956		520323	
		374830		488265	
3143	29	480929		476119	
		488143	$\bar{x}$ 5	485738	$\bar{x}$ 4
		411194	450630 psi	478524	474316 psi
		464096		413599*	
		408789		456882	
3512	44291	449835		509653	
		437817	$\bar{x}$ 4	524010	$\bar{x}$ 5
		346947*	458210 psi	528795	513960 psi
		590512		516832	
		454620		490512	

* Outlier rejection based on Chauvenet's criteria.

Table III. Dry Fiberglass Test Results, Sheet 4 of 7

Item 5. Tensile Strength Per ASTM D2343 Procedure B

Lot No.	Ball No.	Tensile Strength, psi Vinyl Resin		EF-2 Resin	
2988	12	390385		545569	
		370987	$\bar{x}$ 5	557692	$\bar{x}$ 4
		387960	386990 psi	562542	552843 psi
		397659		545569	
		387960		424331*	
2988	14	401167		514750	
		357667*	$\bar{x}$ 5	522000	$\bar{x}$ 5
		466417*	409867 psi	563083	518133 psi
		418083		526833	
		406000		464000	
3143	23	424150		505527	
		369898	$\bar{x}$ 5	453741	$\bar{x}$ 5
		364966	393571 psi	530187	487772 psi
		401956		485799	
		406888		463605	
3143	29	478524		420813	
		468905	$\bar{x}$ 5	533831	$\bar{x}$ 5
		449668	464577 psi	524212	474677 psi
		442454		428027	
		483333		466501	
3512	44291	421122		524010	
		392409	$\bar{x}$ 5	473762	$\bar{x}$ 5
		358911	373267 psi	468977	489076 psi
		349340		490512	
		344554		488119	

* Outlier rejection based on Chauvenet's criteria.

Table III. Dry Fiberglass Test Results, Sheet 5 of 7

Item 6. Horizontal Shear Strength Per WS 1126/ASPC 34421

Lot No.	Ball No.	Horizontal Shear Strength, psi: 250°F Test Temperature		After 2 Hour Water Boil	
2988	12	4616		9096	
		4326	$\bar{x}$ 5	8376	$\bar{x}$ 5
		4500	4504 psi	8582	8384 psi
		4518		7440	
		4561		8427	
2988	14	4629		8698	
		4378	$\bar{x}$ 5	9656	$\bar{x}$ 5
		4464	4545 psi	8722	9068 psi
		4519		8746	
		4734		9518	
3143	23	4651		8772	
		4524	$\bar{x}$ 5	8224	$\bar{x}$ 5
		4524	4616 psi	8041	8226 psi
		4843		8721	
		4537		7374	
3143	29	4960		8434	
		4476	$\bar{x}$ 5	9280	$\bar{x}$ 5
		4615	4741 psi	8667	8757 psi
		4800		8607	
		4856		8796	
3512	44291	4362		8618	
		4500	$\bar{x}$ 5	9419	$\bar{x}$ 5
		4458	4400 psi	8675	8974 psi
		4337		8952	
		4344		9205	

Table III. Dry Fiberglass Test Results, Sheet 6 of 7

Item 7. Horizontal Shear Strength Per ASTM D-2344

Lot No.	Ball No.	250°F Test Temperature		After 2 Hour Water Bath	
2988	12	3735		8247	
		3774	$\bar{x}$ 5	7711	$\bar{x}$ 5
		3826	3896 psi	8305	8100 psi
		3912		8100	
		4232		8138	
2988	14	3659		6557	
		3707	$\bar{x}$ 5	6508	$\bar{x}$ 5
		3551	3691 psi	6899	6839 psi
		3675		7275	
		3862		6956	
3143	23	4433		8407	
		4428	$\bar{x}$ 5	8247	$\bar{x}$ 5
		4277	4325 psi	8588	8571 psi
		4277		8614	
		4212		9000	
3143	29	4210		8314	
		4269	$\bar{x}$ 5	8455	$\bar{x}$ 5
		4331	4287 psi	8529	8306 psi
		4280		8281	
		4347		7953	
3512	44291	4008		9207	
		4174	$\bar{x}$ 5	9315	$\bar{x}$ 5
		4052	4103 psi	9221	9113 psi
		4137		9624	
		4146		8198	

Table III. Dry Fiberglass Test Results, Sheet 7 of 7

Item 8. Acetone Extractables, Extraction Loss and Insolubles

Lot No.	Ball No.	% Extractables		% Extraction Loss		% Insolubles	
2988	12	86.05	$\bar{x}$ 3	1.41	$\bar{x}$ 3	0.23	$\bar{x}$ 3
		85.98	86.00%	1.43	1.43 %	0.23	0.23%
		85.97		1.44		0.24	
2988	14	90.32	$\bar{x}$ 3	1.63	$\bar{x}$ 3	0.17	$\bar{x}$ 3
		90.05	90.14%	1.63	1.64%	0.18	0.18%
		90.05		1.65		0.18	
3143	23	83.98	$\bar{x}$ 3	1.26	$\bar{x}$ 3	0.24	$\bar{x}$ 3
		84.97	84.35%	1.26	1.26%	0.22	0.23%
		84.10		1.26		0.24	
3143	29	89.41	$\bar{x}$ 3	1.47	$\bar{x}$ 3	0.17	$\bar{x}$ 3
		88.96	89.05%	1.47	1.47%	0.18	0.18%
		88.78		1.48		0.19	
3512	44291	100.00	$\bar{x}$ 3	1.42	$\bar{x}$ 3	0.00	$\bar{x}$ 3
		95.76	98.59%	1.42	1.42%	0.06	0.02%
		100.00		1.43		0.00	

Table IV. Impregnated Fiberglass Test Results, Sheet 1 of 6

Items 1., 2., and 3. - Volatiles, Ignition Loss, and Weight per Linear Yard

Lot #	Ball #	Volatiles, Wt.%		Ignition Loss, Wt.%		Weight/Linear Yard, gms/yd.	
2988	12	1.2	$\bar{x}_3$	18.7	$\bar{x}_3$	0.596	$\bar{x}_3$
		1.1	1.2	18.5	18.6	0.596	0.596
		1.2		18.6		0.597	
2988	14	1.5	$\bar{x}_3$	19.9	$\bar{x}_3$	0.596	$\bar{x}_3$
		1.4	1.4	19.5	19.7	0.595	0.595
		1.3		19.6		0.595	
3143	23	1.3	$\bar{x}_3$	19.0	$\bar{x}_3$	0.591	$\bar{x}_3$
		1.5	1.4	18.9	19.0	0.593	0.592
		1.4		19.1		0.593	
3143	29	1.4	$\bar{x}_3$	18.7	$\bar{x}_3$	0.599	$\bar{x}_3$
		1.4	1.4	18.7	18.8	0.599	0.599
		1.3		18.9		0.599	
3512	44291	1.1	$\bar{x}_3$	17.7	$\bar{x}_3$	0.603	$\bar{x}_3$
		1.1	1.1	17.9	17.8	0.605	0.604
		1.1		17.8		0.604	

Table IV. Impregnated Fiberglass Test Results, Sheet 2 of 6

Items 4. and 5. - Resin Flow and Gel Time

Lot #	Ball #	Resin Flow, Wt. %		Gel Time, minutes	
2988	12	10.83	$\bar{x}_3$	2.5	$\bar{x}_3$
		8.65	9.14%	2.6	2.6
		7.95		2.6	
2988	14	12.52	$\bar{x}_3$	2.2	$\bar{x}_3$
		11.03	9.58%	2.2	2.2
		5.19		2.3	
3143	23	7.13	$\bar{x}_3$	2.3	$\bar{x}_3$
		5.97	6.51%	2.2	2.3
		6.42		2.3	
3143	29	11.20	$\bar{x}_3$	2.3	$\bar{x}_3$
		10.25	9.72%	2.3	2.3
		7.72		2.3	
3512	44291	9.59	$\bar{x}_3$	2.4	$\bar{x}_3$
		9.03	8.72%	2.3	2.4
		7.54		2.5	

Table IV. Impregnated Fiberglass Test Results, Sheet 3 of 6

Item 6. - Horizontal Shear Strength per WS 1128/ASPC 34422

Lot #	Ball #	Horizontal Shear Strength, PSI: 250°F Test Temperature		After 2 hr. Water Boil	
2988	12	4134		13162	
		4218	$\bar{x}_5$ 3963	13459	$\bar{x}_5$ 13386
		4174		12992	
		4216		13696	
		3071		13623	
2988	14	2760		12732	
		2598	$\bar{x}_5$ 2799	12767	$\bar{x}_5$ 13072
		2623		13666	
		2881		13241	
		3132		12952	
3143	23	3202		13476	
		2824	$\bar{x}_5$ 3063	13453	$\bar{x}_5$ 13343
		3388		13169	
		3164		13641	
		2738		12976	
3143	29	3128		13607	
		3398	$\bar{x}_5$ 3264	13944	$\bar{x}_5$ 13557
		3222		13183	
		3282		13213	
		3291		13838	
3512	44291	3546		13600	
		3463	$\bar{x}_5$ 3449	13294	$\bar{x}_5$ 13461
		3647		13478	
		3366		13412	
		3223		13519	

Table IV. Impregnated Fiberglass Test Results, Sheet 4 of 6

Item 7. - Horizontal Shear Strength per ASTM D2344

Lot #	Ball #	Horizontal Shear Strength, PSI: 250°F Test Temperature		Horizontal Shear Strength, PSI: After 2 hr. Water Boil	
2988	12	7625		11044	
		7388	$\bar{x}_5$ 6872	11399	$\bar{x}_5$ 11179
		6000		11339	
		6048		11171	
		6800		10944	
2988	14	3282		11102	
		3389	$\bar{x}_5$ 3384	11235	$\bar{x}_5$ 11240
		3367		11176	
		3476		11732	
		3405		10952	
3143	23	7352		11339	
		6285	$\bar{x}_5$ 7034	10965	$\bar{x}_5$ 11370
		8989		11324	
		6047		11753	
		6496		11471	
3143	29	5438		11570	
		5398	$\bar{x}_5$ 6425	11383	$\bar{x}_5$ 11370
		5439		11620	
		8715		11520	
		7164		10757	
3512	44291	2571		10977	
		2561	$\bar{x}_5$ 2621	11159	$\bar{x}_5$ 11048
		2683		11054	
		2633		11054	
		2659		10996	

Table IV. Impregnated Fiberglass Test Results, Sheet 5 of 6

Item 8. - Tensile Strength per WS 1128/ASPC 34422

Lot #	Ball #	Tensile Strength, PSI	
2988	12	510906	$\bar{x}_3$
		532802	519827
		515772	
2988	14	545882	$\bar{x}_3$
		538571	538571
		531261	
3143	23	477618	$\bar{x}_3$
		514358	493947
		489865	
3143	29	527713	$\bar{x}_3$
		522871	523451
		510768	
3512	44291	532947	$\bar{x}_3$
		518543	522544
		516142	

Table IV. Impregnated Fiberglass Test Results, Sheet 6 of 6

Items 9. and 10. - Tensile Strength per ASTM 2343, Procedures A and B

Lot #	Ball #	Tensile Strength, PSI Procedure A		Procedure B	
2988	12	484144		537668	
		510906	$\bar{x}_5$ 482192	515772	$\bar{x}_5$ 522197
		413591		537668	
		496309		501769	
		506010		518106	
2988	14	448403		560534	
		426471	$\bar{x}_5$ 422572	558067	$\bar{x}_5$ 542958
		421597		548319	
		419160		538571	
		397227		509328	
3143	23	492314		548649	
		541301	$\bar{x}_5$ 521216	526605	$\bar{x}_5$ 524645
		538851		538851	
		533953		494764	
		499662		514358	
3143	29	532554		508347	
		503506	$\bar{x}_5$ 525776	532554	$\bar{x}_5$ 527229
		520451		527713	
		532554		564023	
		539816		503506	
3512	44291	530546		552152	
		523344	$\bar{x}_5$ 517103	554553	$\bar{x}_5$ 540149
		513742		528146	
		511341		525745	
		506540		540149	

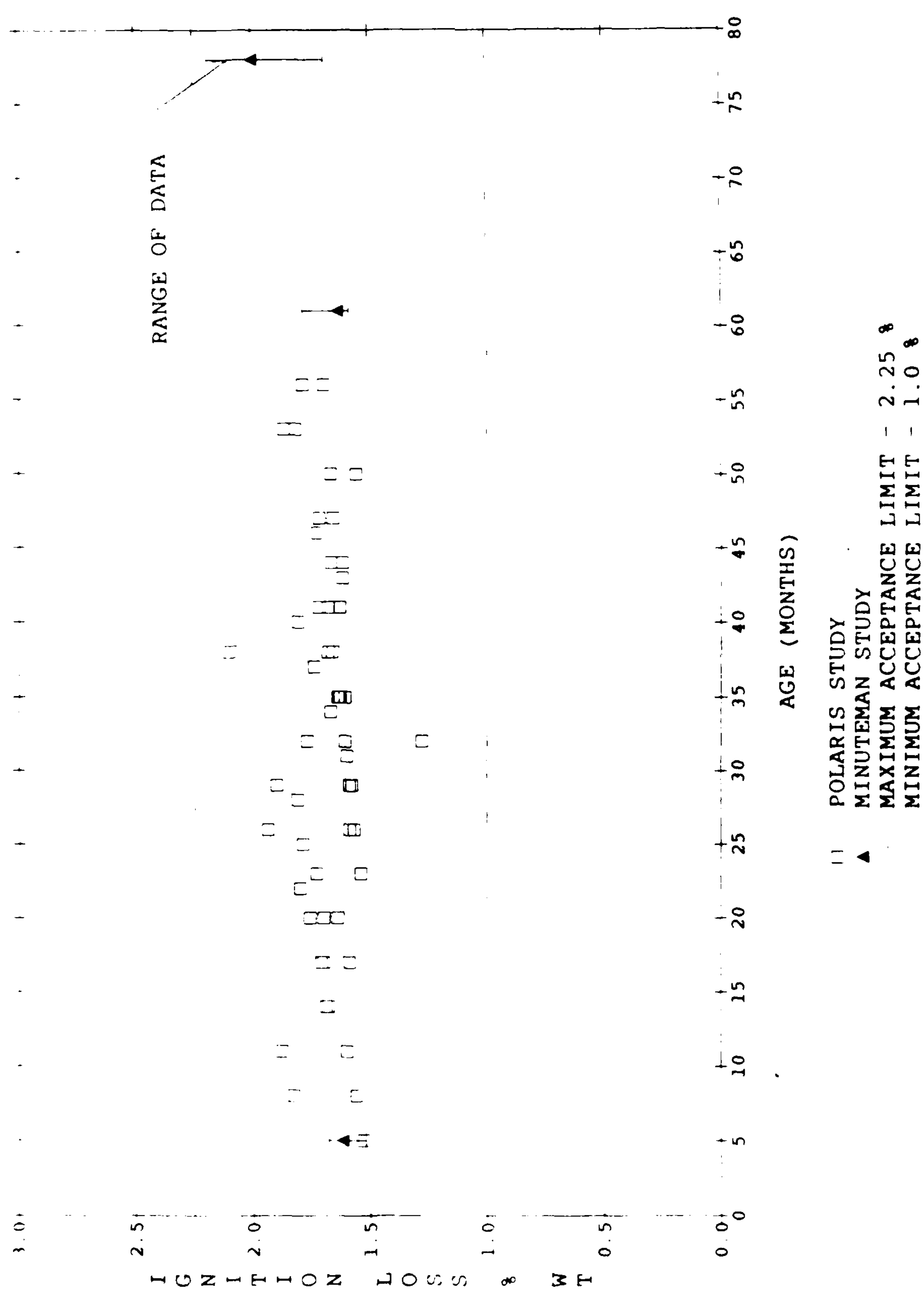

Figure 1. S-901 Dry Fiberglass Ignition Loss WS 1126/ASPC 34421

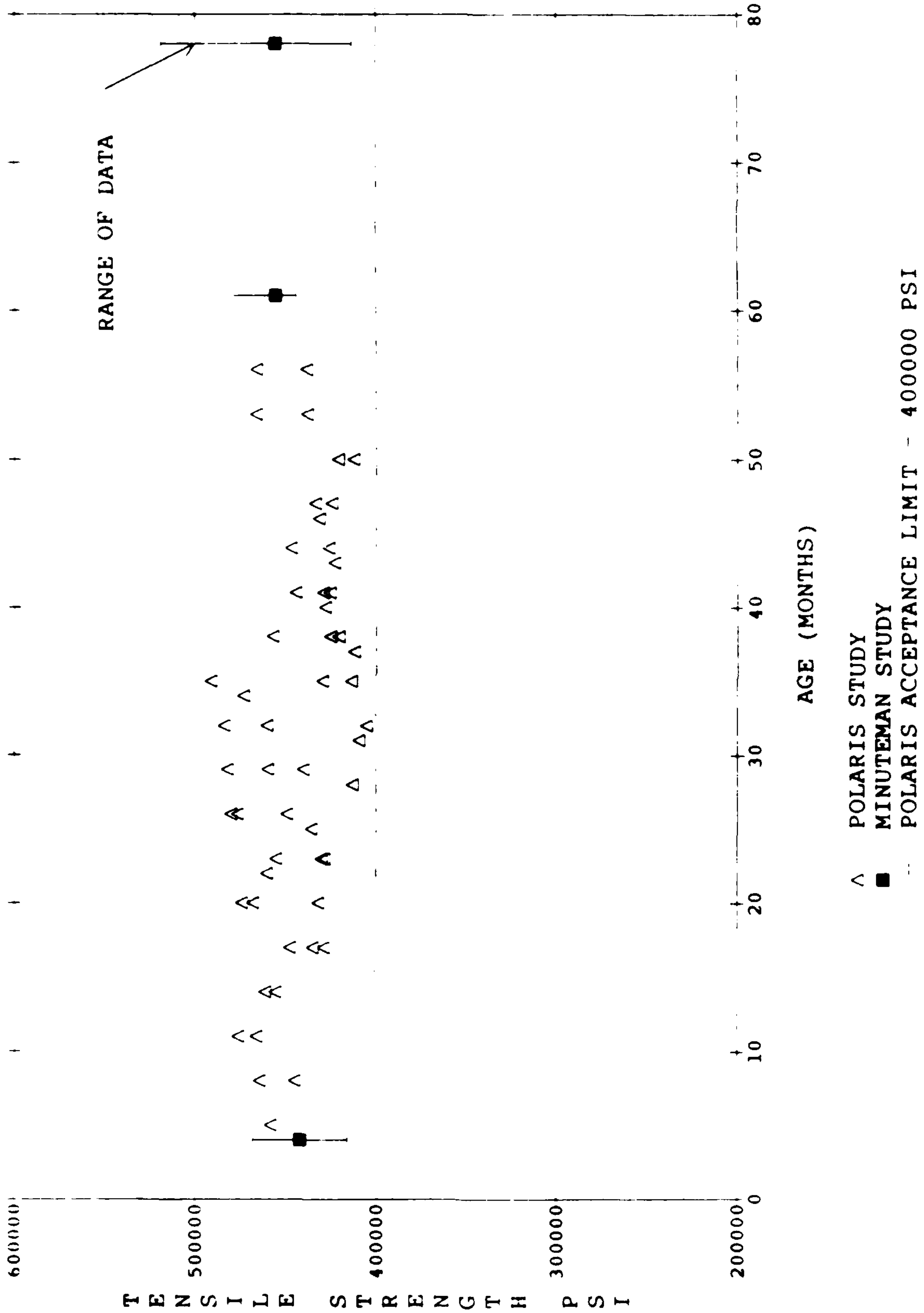

Figure 2. Dry Fiberglass Tensile Strength (Vinyl Resin) WS 1126/ASPC 34421
Comparison To Polaris Study

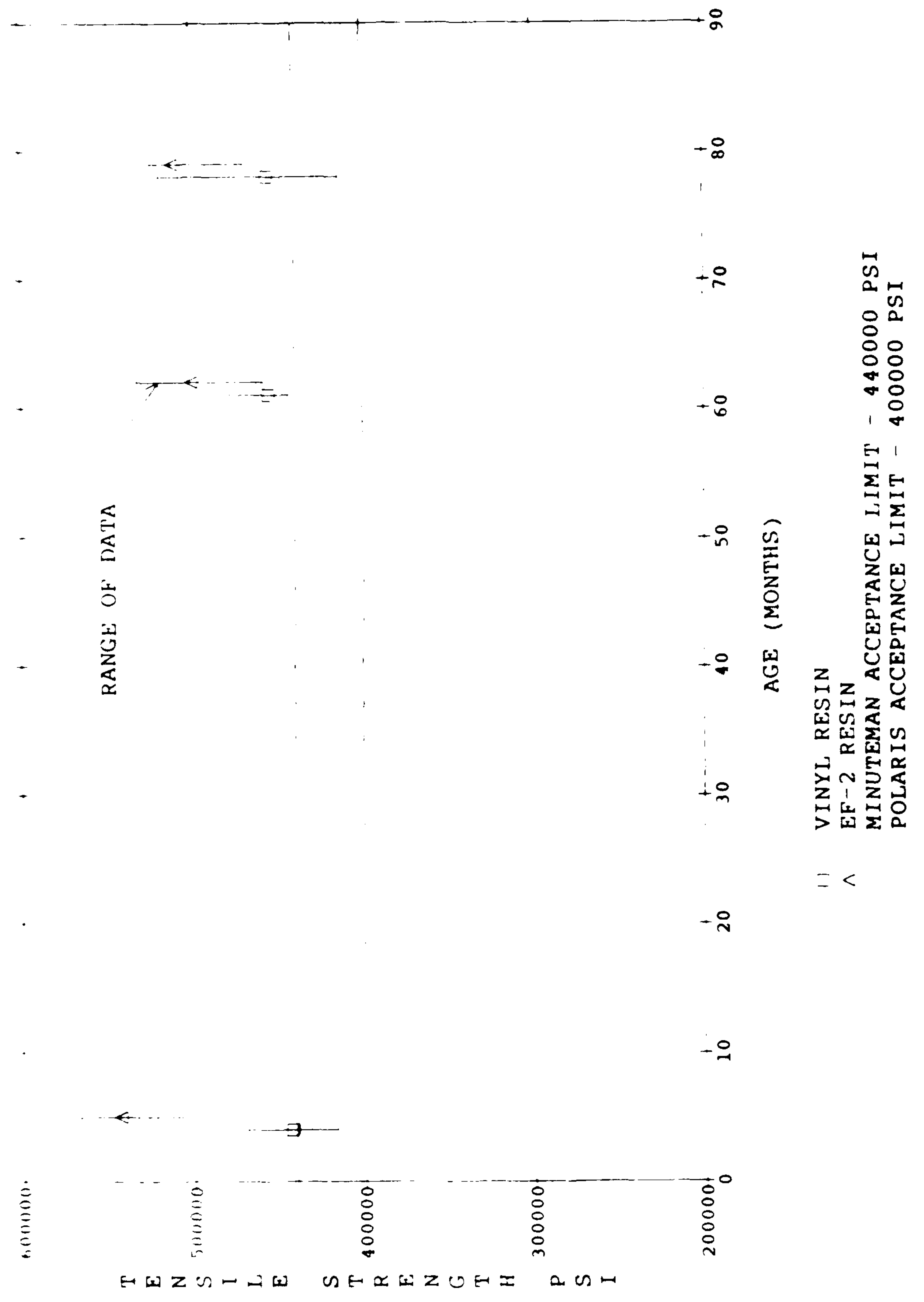

Figure 3. Dry Fiberglass Tensile Strength WS 1126/ASPC 34421 EF-2 Resin Compared To Vinyl Resin

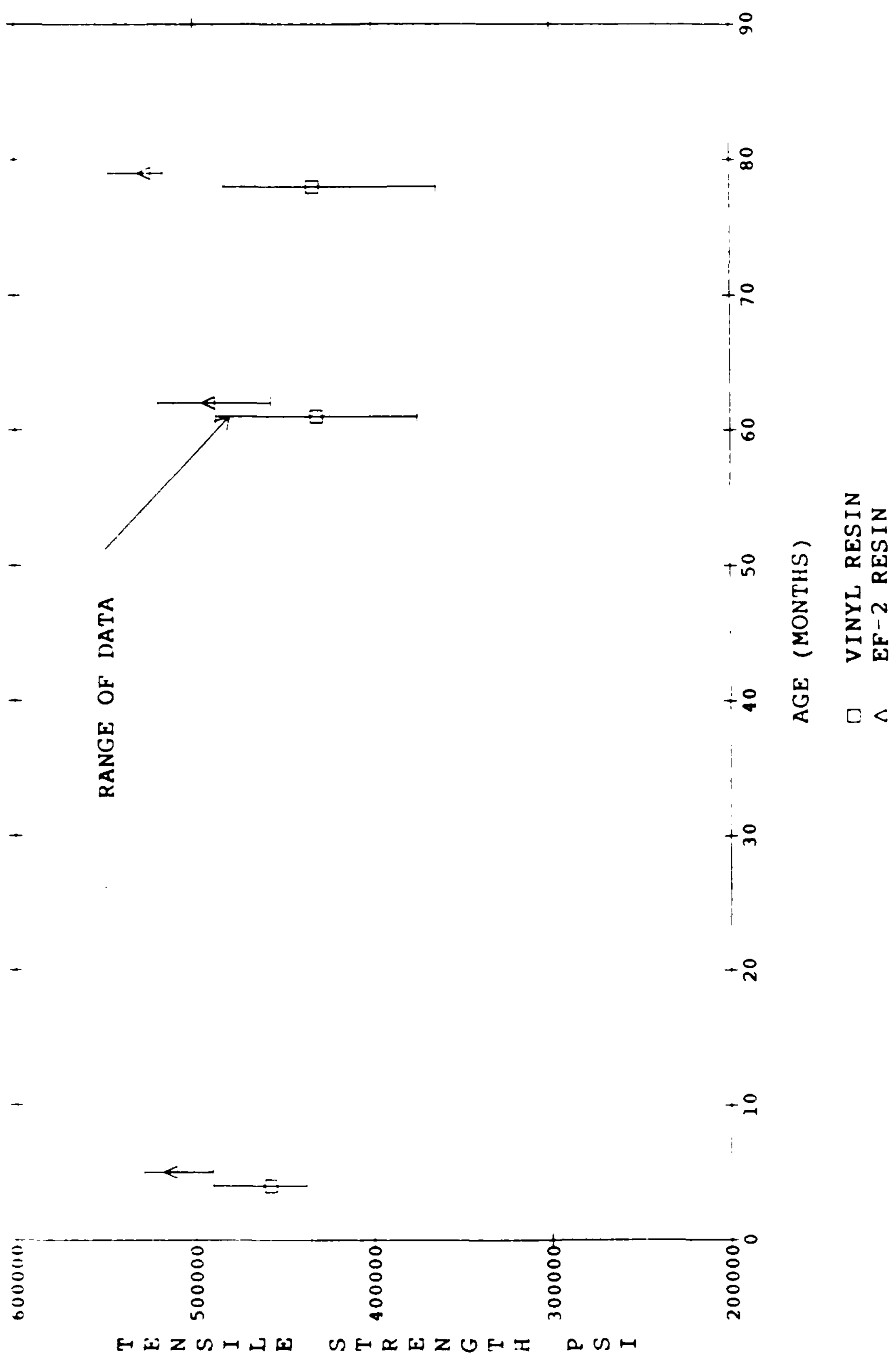

Figure 4. Dry Fiberglass Tensile Strength Tested According To ASTM D2343 Procedure A

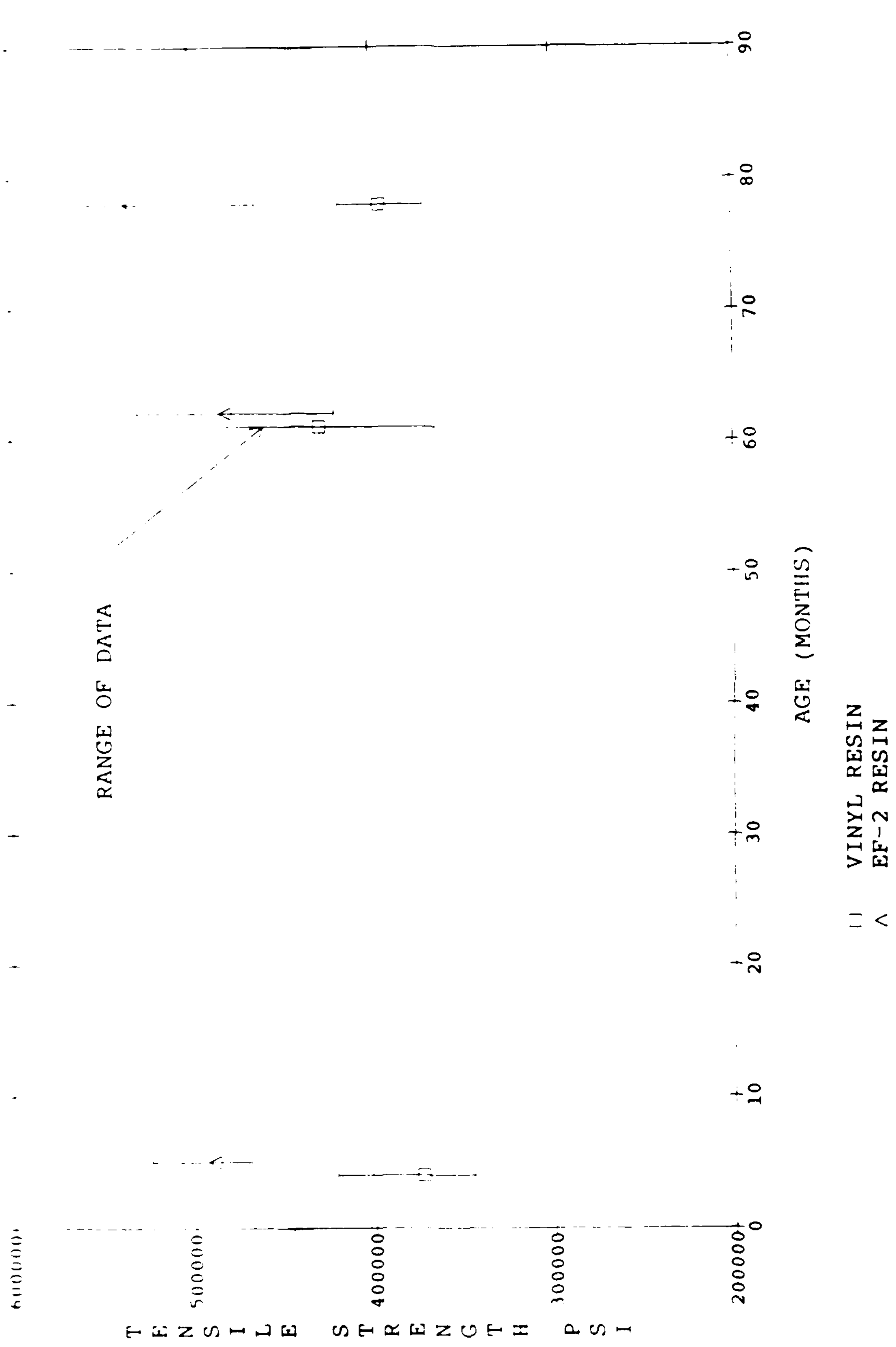

Figure 5. Dry Fiberglass Tensile Strength Tested According To ASTM D2343 Procedure B

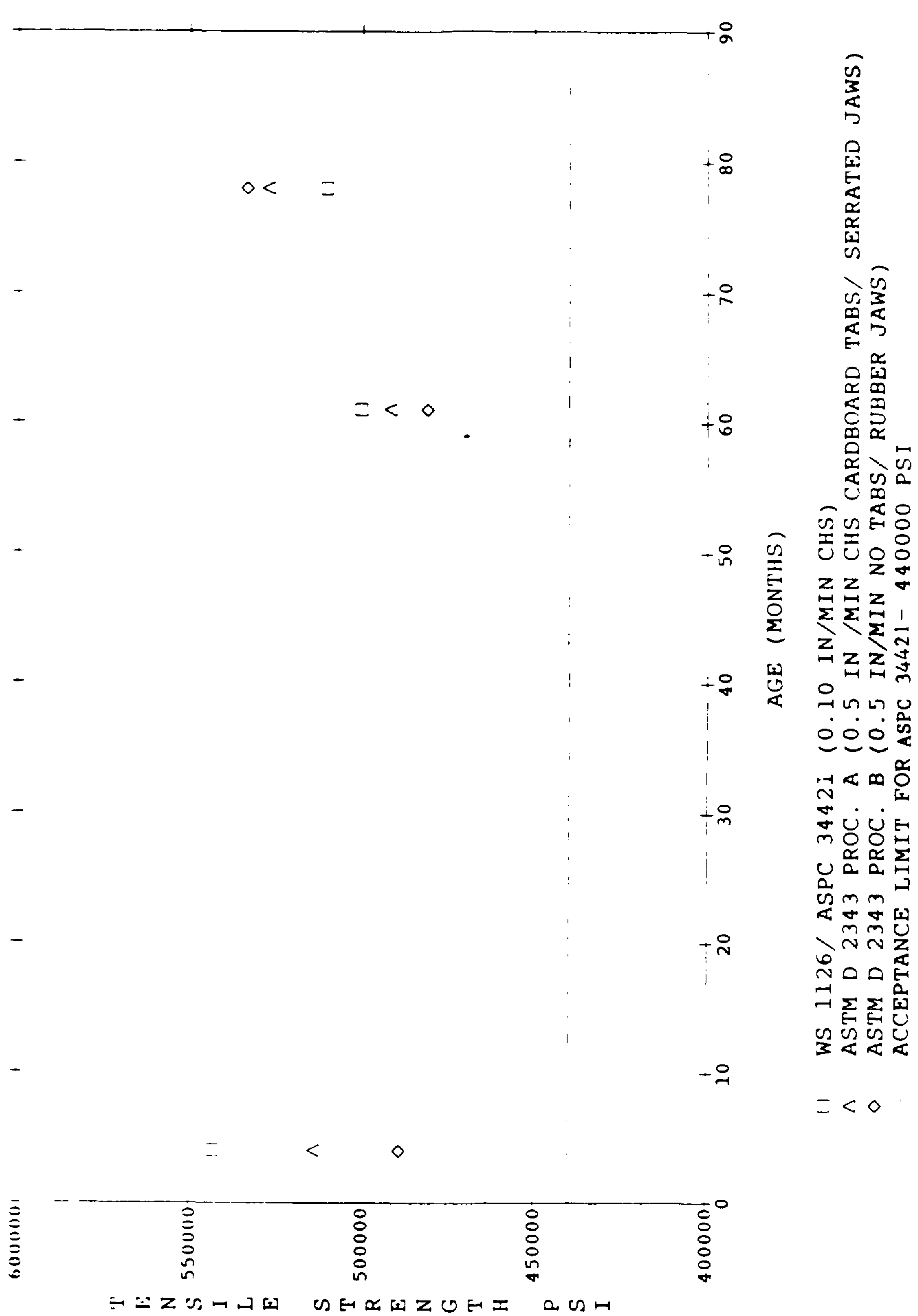

Figure 6. Dry Fiberglass Tensile Strength (EF-2 Resin) Comparison of Three Test Methods Used

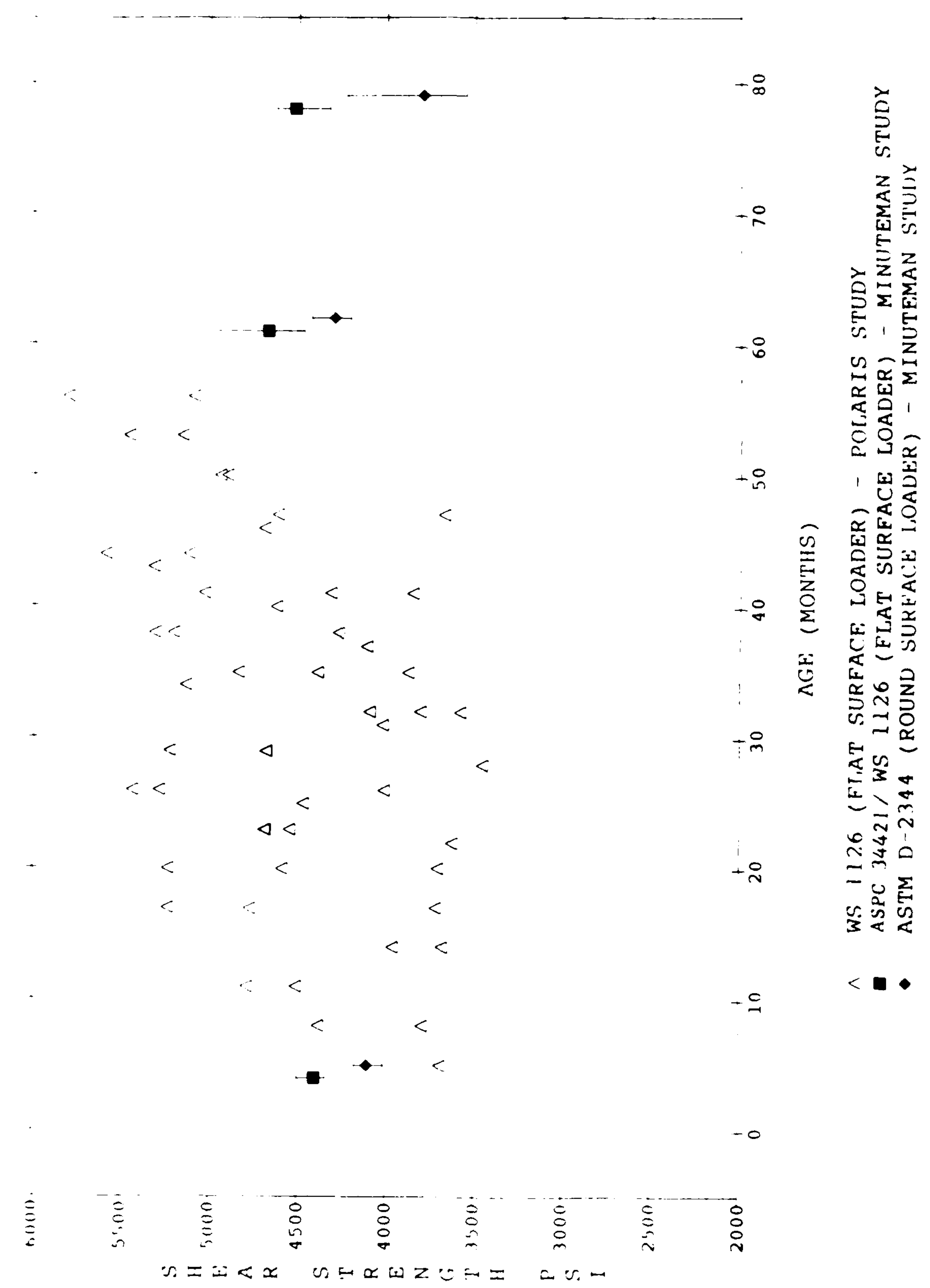

Figure 7. Dry Fiberglass Short Beam Shear at 250°F

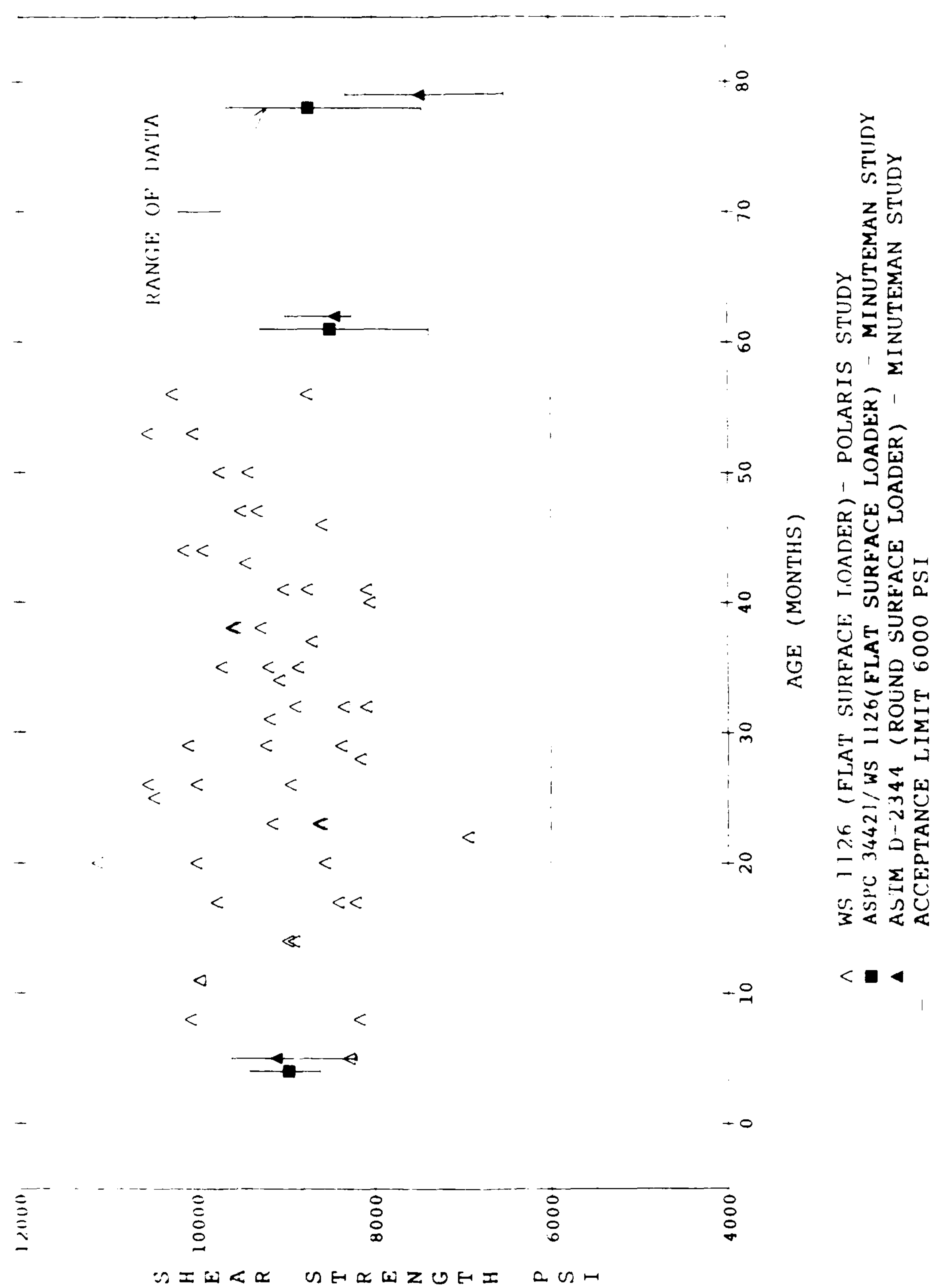

Figure 8. S-901 Dry Fiberglass Short Beam Shear After 2 Hour Water Boil

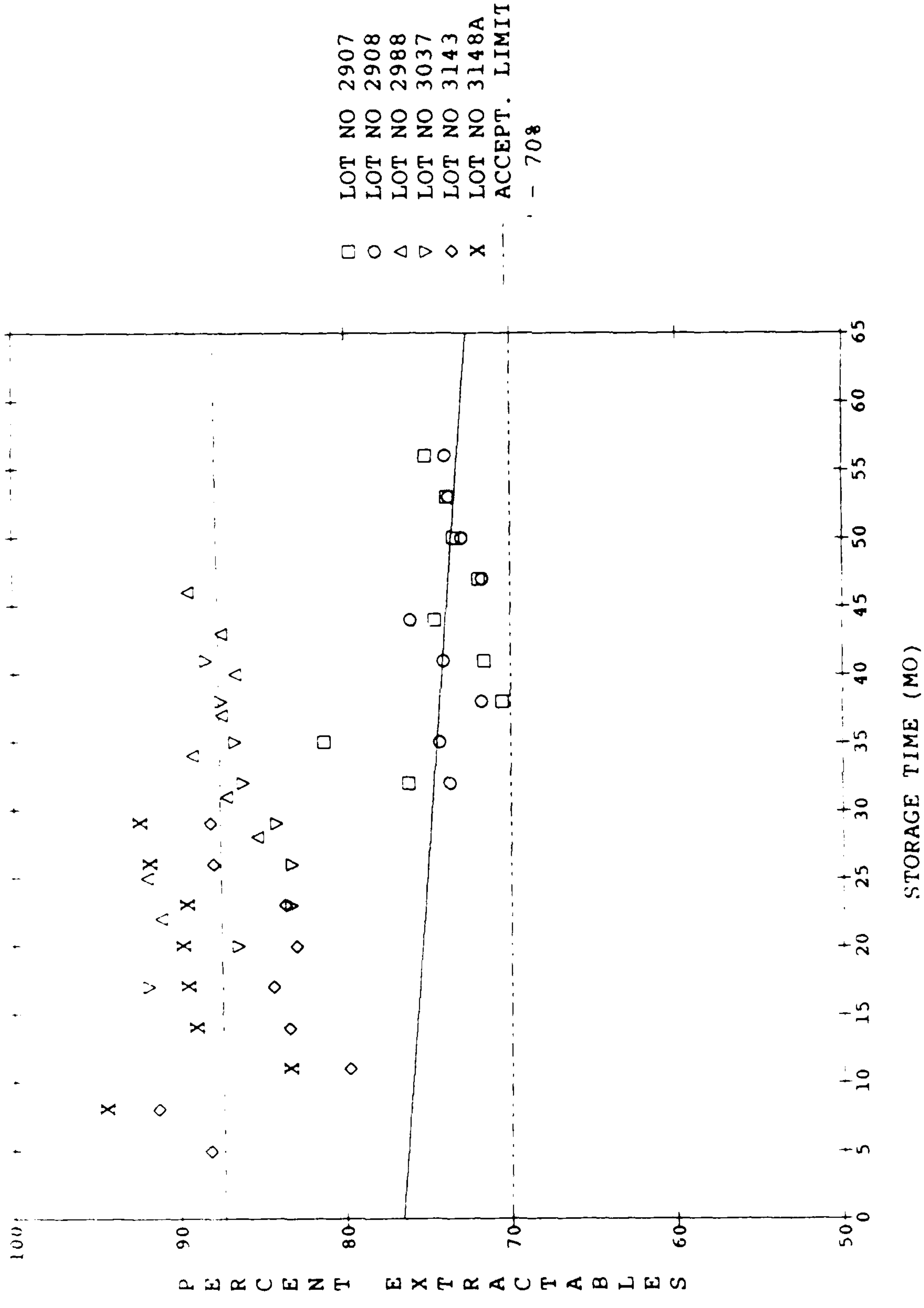

Figure 9. Dry Fiberglass Acetone Extractables Results from Polaris Study

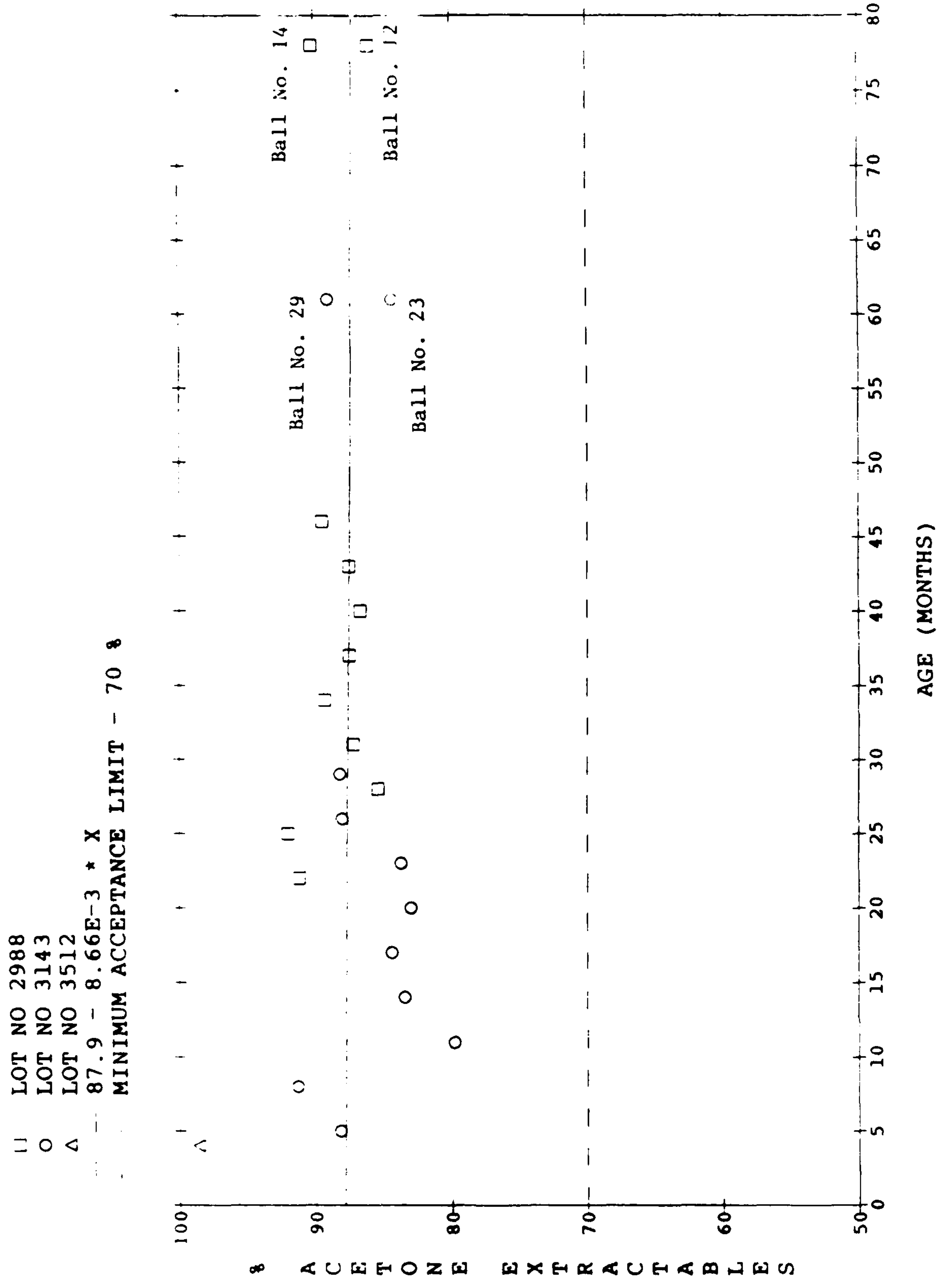

Figure 10. Dry Fiberglass Acetone Extractables Minuteman Study

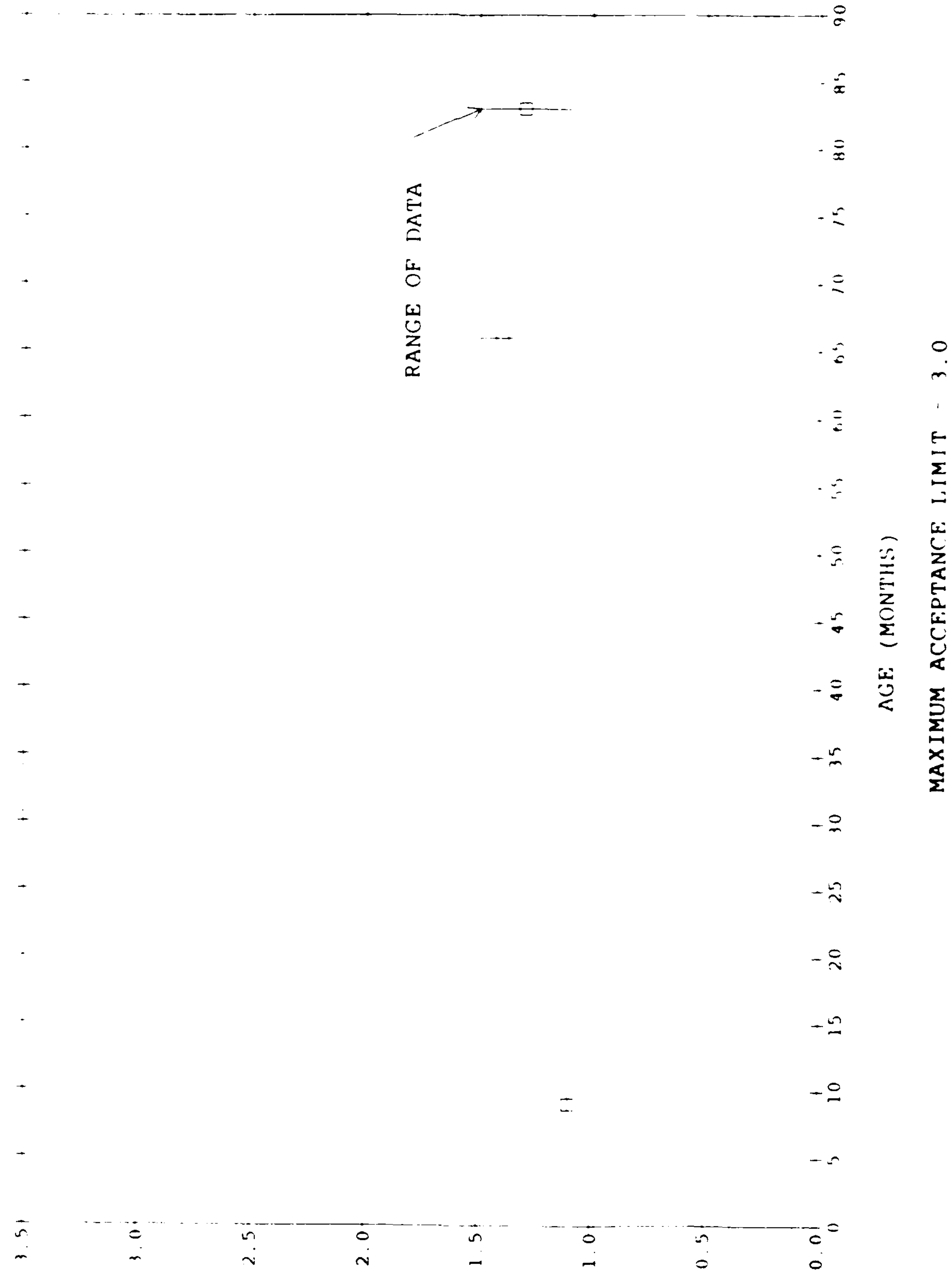

Figure 11. Impregnated S-901 Fiberglass Volatiles

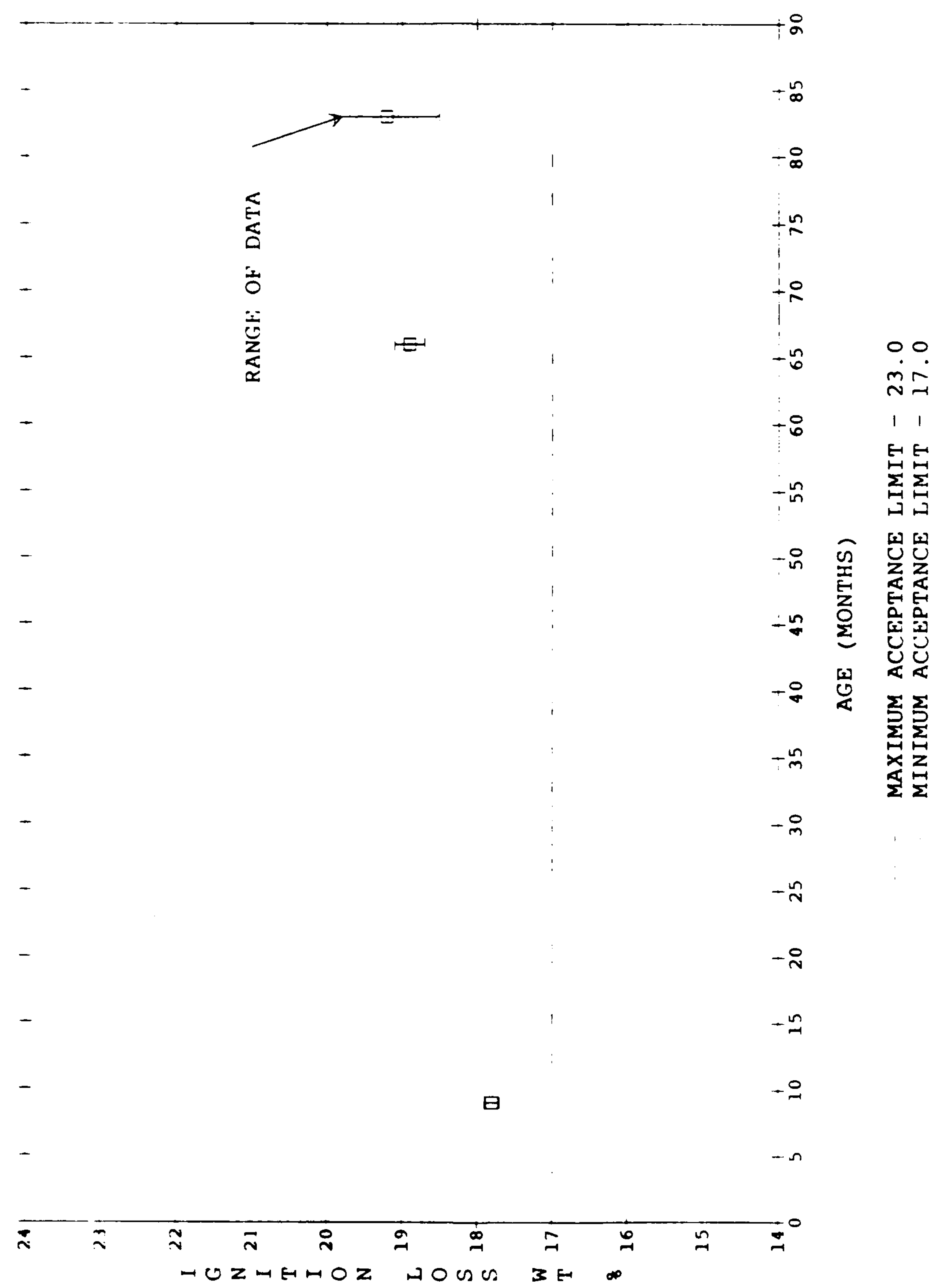

Figure 12. Impregnated S-901 Fiberglass Ignition Loss

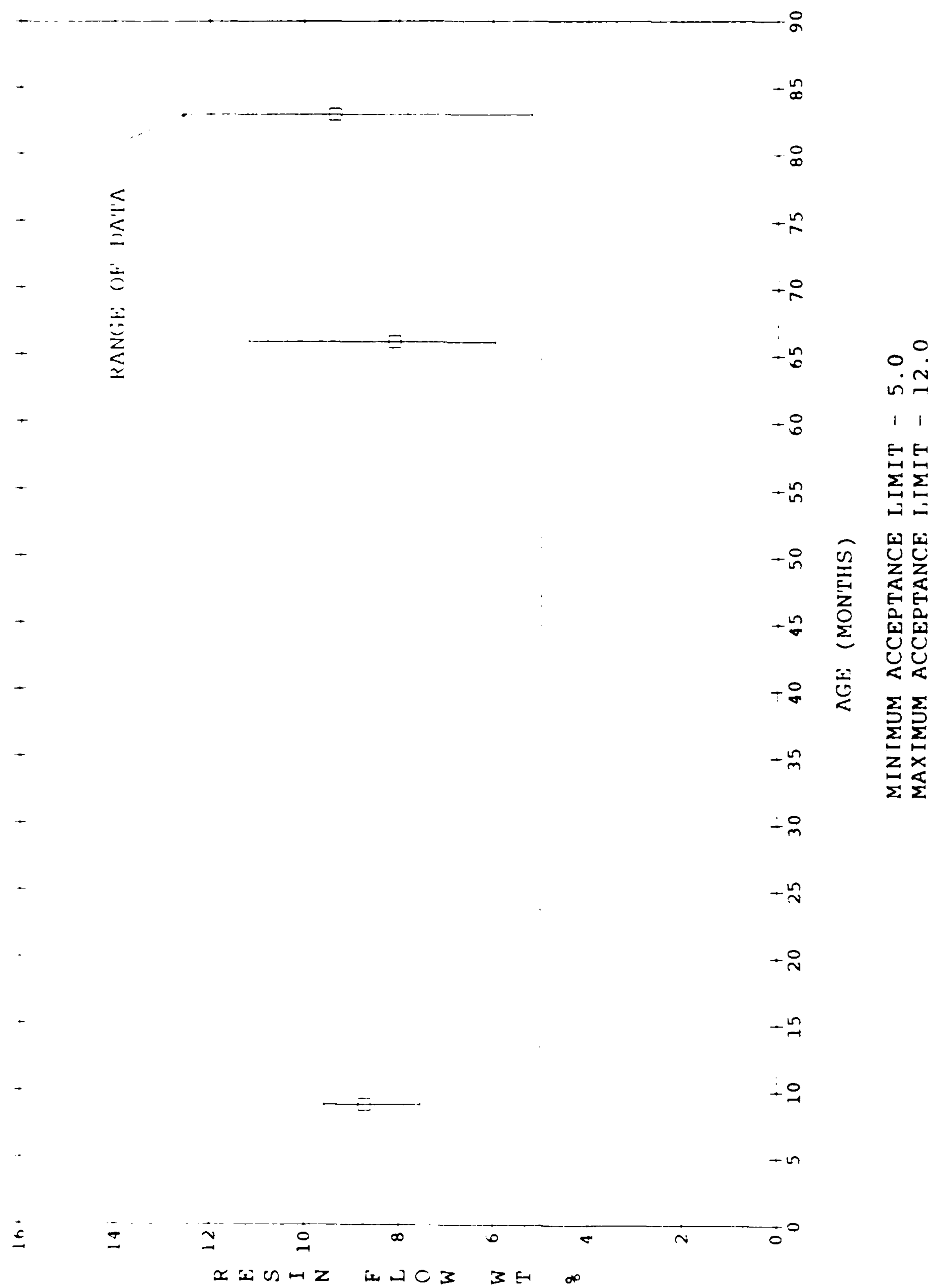

Figure 13. Impregnated S-901 Fiberglass Resin Flow

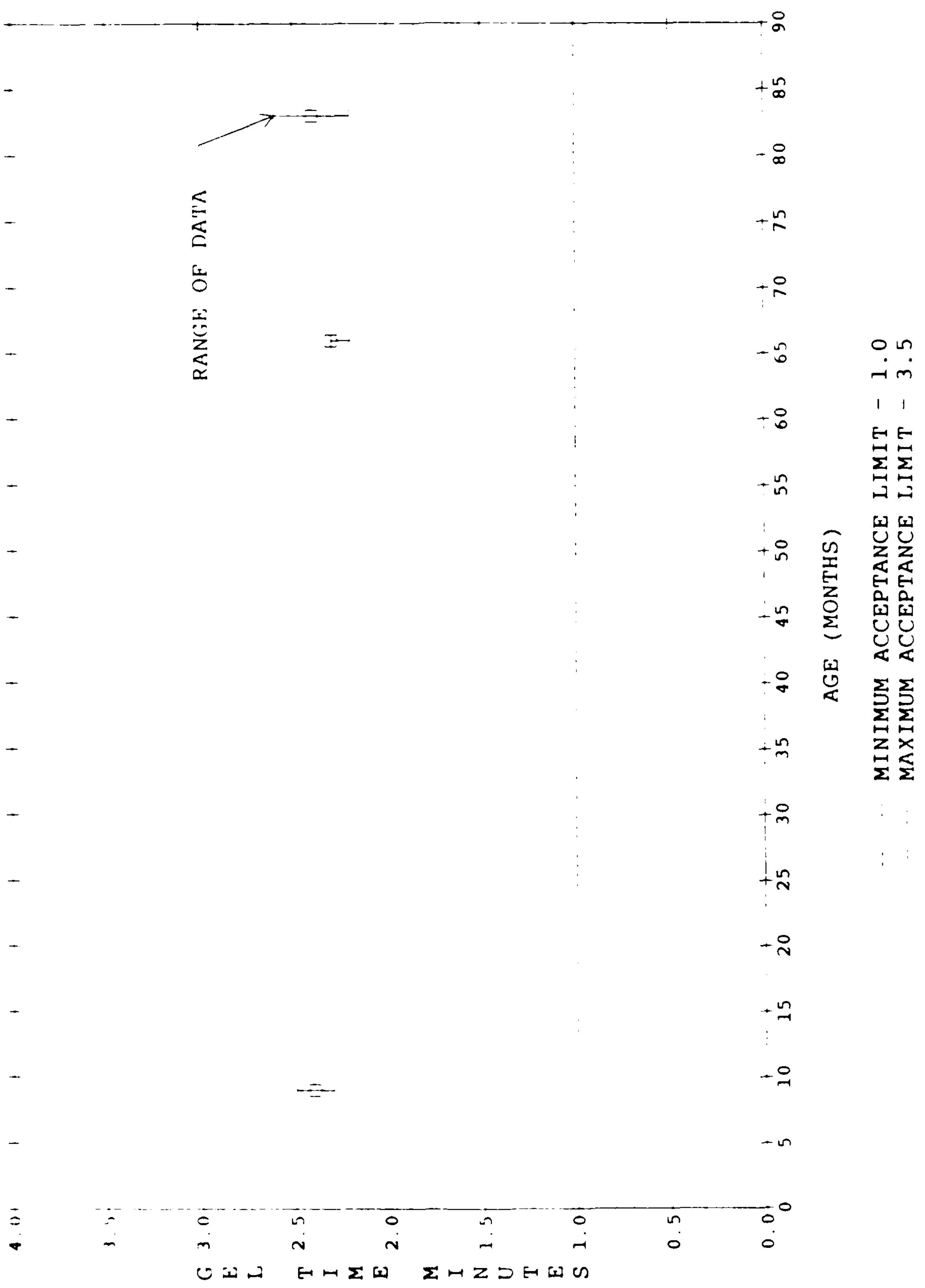

Figure 14. Impregnated S-901 Fiberglass Gel Time

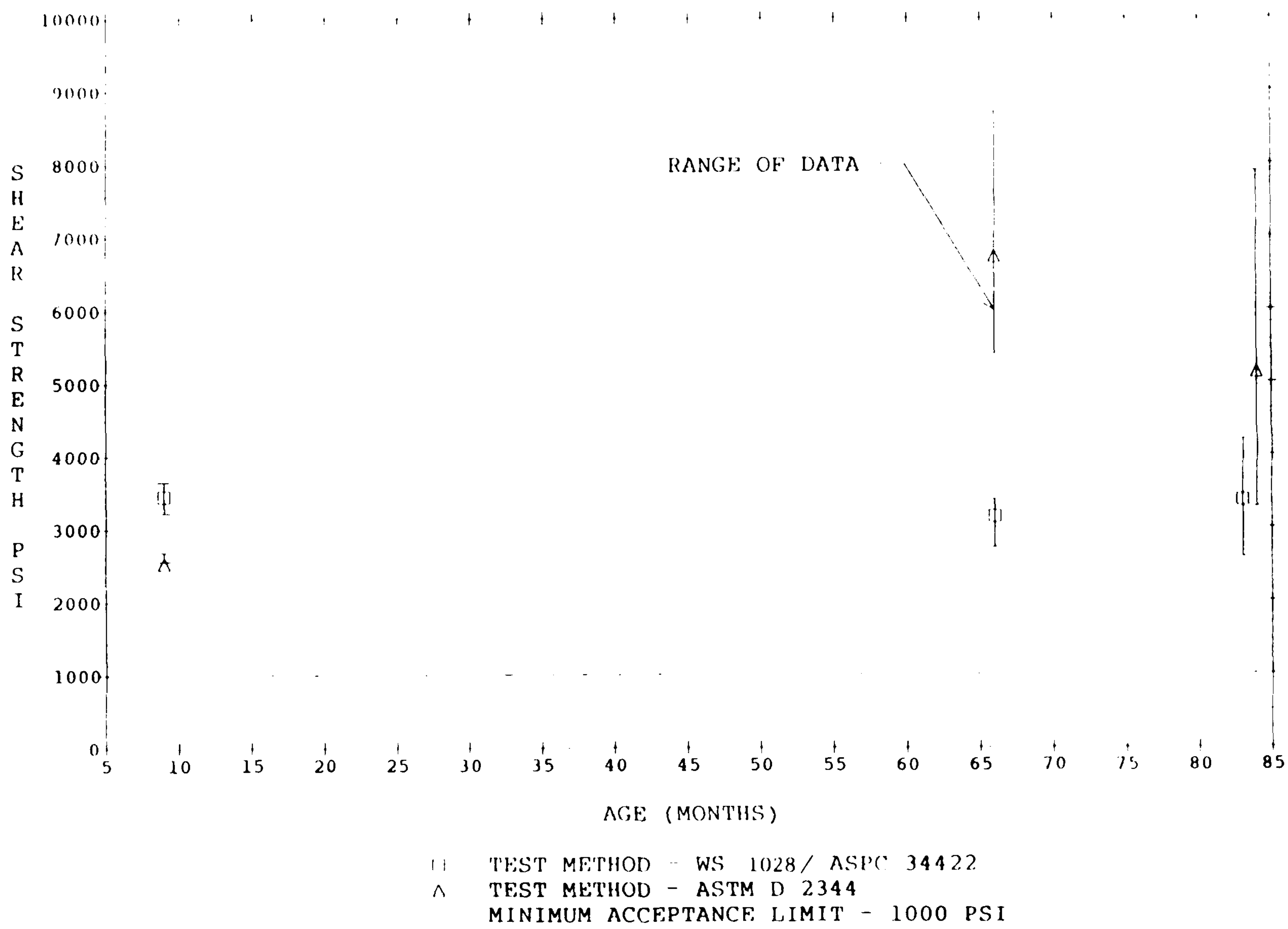

Figure 15. Impregnated S-901 Fiberglass Short Beam Shear At 250°F

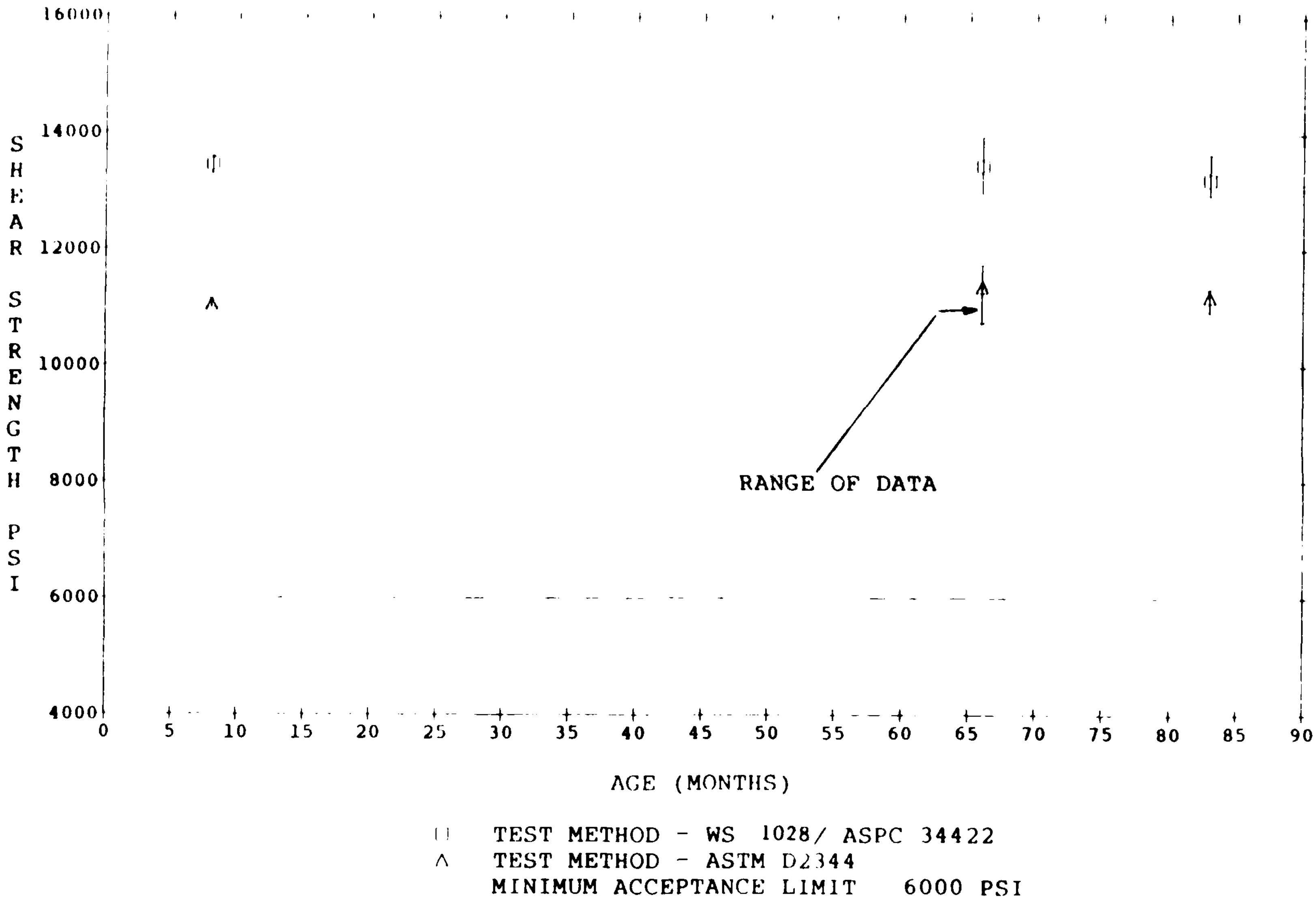

Figure 16. Impregnated S-901 Fiberglass Short Beam Shear After 2 Hour Water Boil

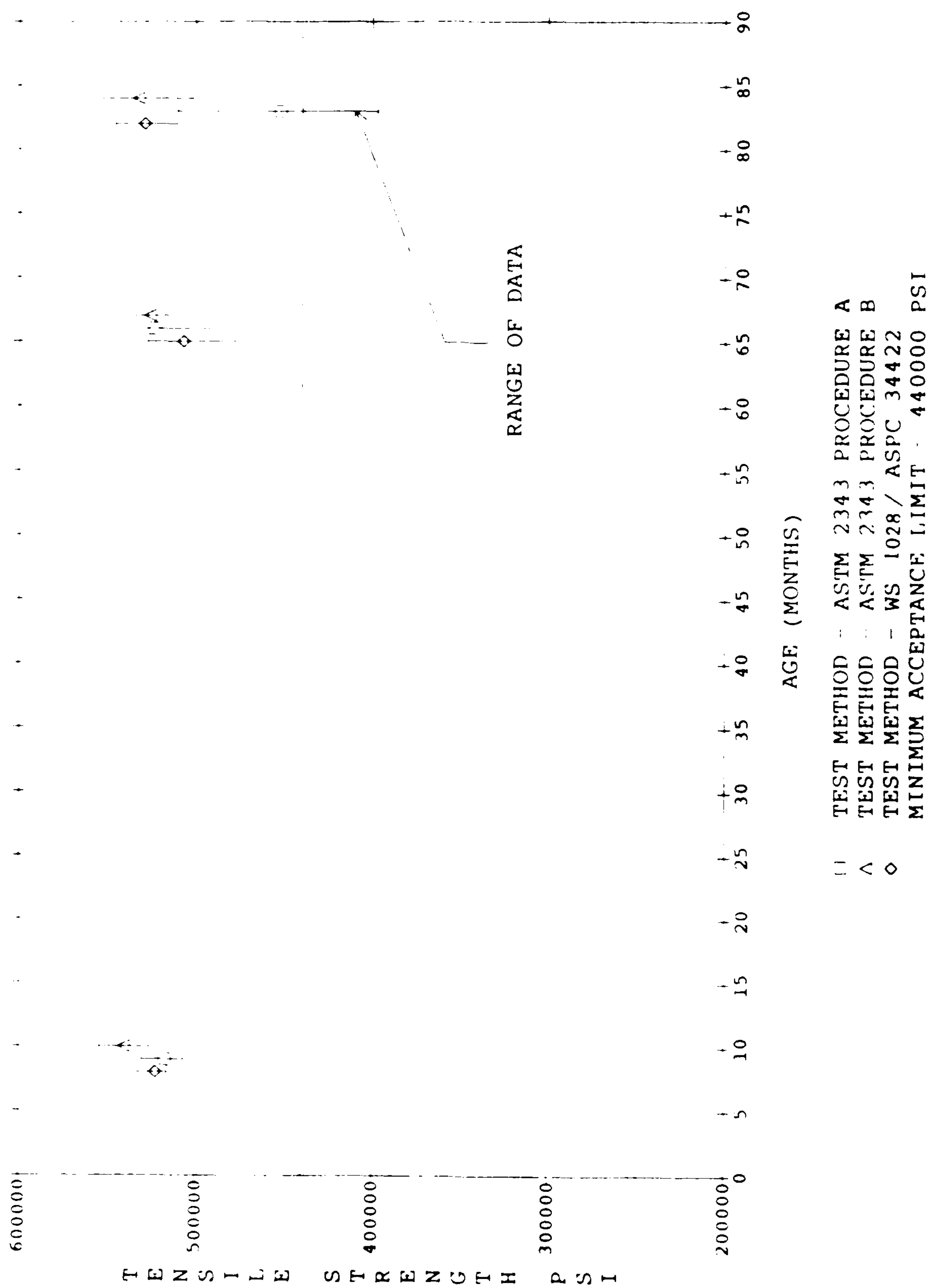

Figure 17. Impregnated S-901 Fiberglass Tensile Strength